Optical Tracking of Space Debris

Overview of ISON's Capabilities and Future Plans

Igor Molotov

ISON

im62@mail.ru

www.lfvn.astronomer.ru

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Methods of Space Debris research

- **Low Earth Orbits (LEO) are investigated mainly with radar**
- **Geostationary (GEO) and medium Earth orbits (MEO) are investigated mainly with optical telescopes**
- **High Elliptical Orbit (HEO) – both radar (perigee) and optical (apogee)**
- **Radar – military mainly (space surveillance), optical – military and civilian**

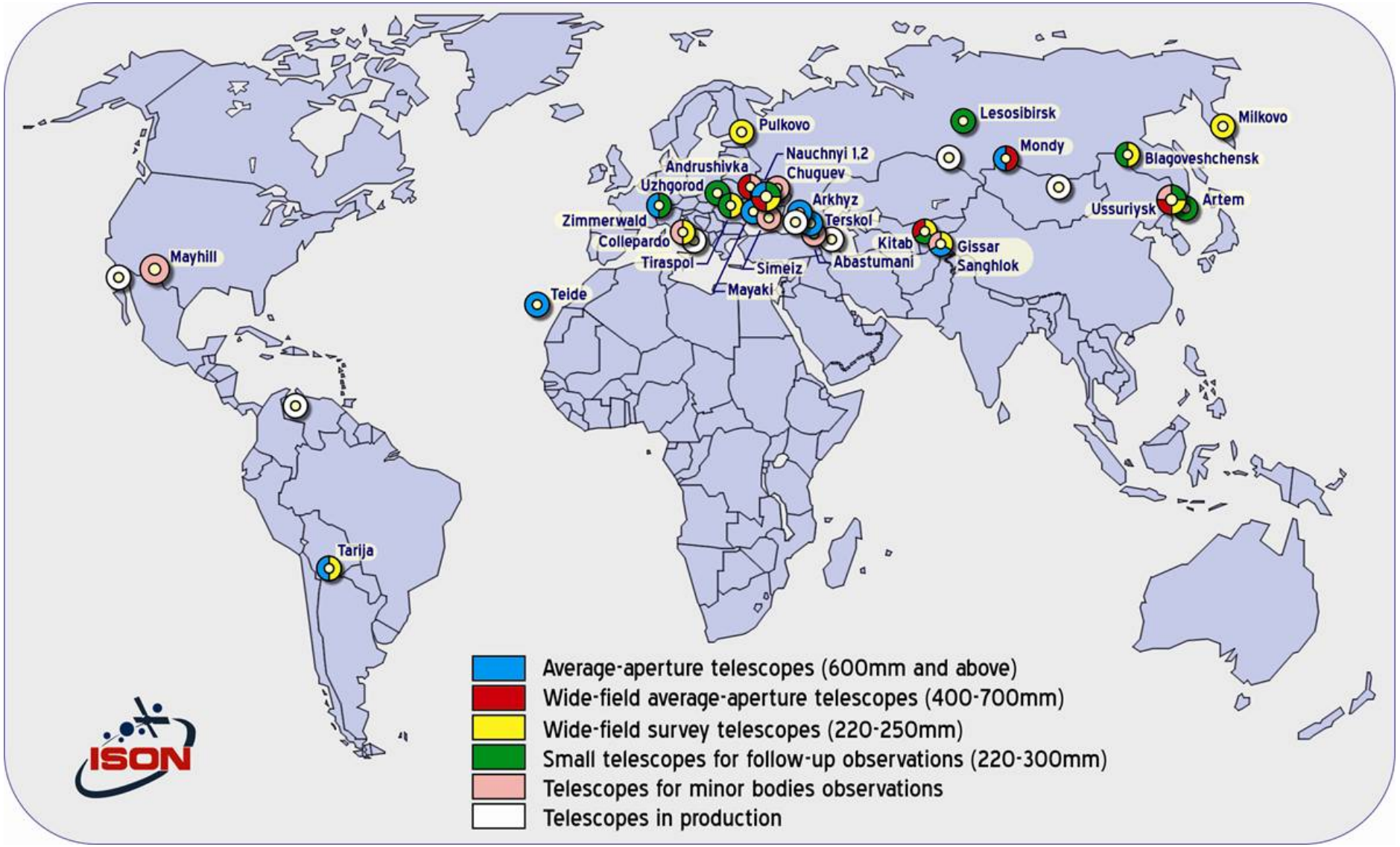
Goals of the space debris observations

- maintaining the dynamical data base on space object orbits
- estimation of real population of artificial objects on high geocentric orbit
- determining of possible origin of the discovered objects
- verification of the space debris distribution and evolution models for high orbits
- estimation of the level of danger caused by space debris objects for operational spacecrafts on high orbits at present and in the future
- control of implementation of measures directed on decreasing the space debris population

To study the space debris at high orbits is necessary to have an extended network of optical sensors

- **ISON is a sample of such network - cooperation already joins 23 observation facilities of various affiliation in 11 countries and is coordinated by the Keldysh Institute of Applied Mathematics of the Russian Academy of Sciences and maintained with assistance of ASC “Project-Technics”, JSC**
- **ISON is an open international non-government project developed to be an independent source of data about space objects for scientific analysis and SSA**
- **Additional scientific goals – asteroids and GRB afterglows**
- **ISON is a reasonable cost solution of space surveillance for high orbits - about 7 millions measurements on 3300 objects are collected that allows us to maintain 35% more complete catalogue than TLE data**

International scientific optical network



ISON is an open international project started in 2004 for regular monitoring of the near-Earth space

ISON milestones:

- **May 2001, first observations with 10-cm telescope in Pulkovo**
- **Autumn 2004, trial observations of faint fragments with 64-cm telescope in Nauchny-1, first join campaigns with European observatories (AIUB, PIMS)**
- **2005-2006 – ISON arrangement and telescope upgrade**
- **2007-2008 – routine observations and new telescopes production. Full GEO coverage achieved**
- **2009 – 2010 – forming ISON subsets for GEO surveys and fain fragment tracking**

25 new telescopes and 40 GPS-based timing devices are produced, 40 CCD cameras are purchased, 10 old telescopes are modernized, standard software for CCD frames reduction and telescope equipment control is elaborated

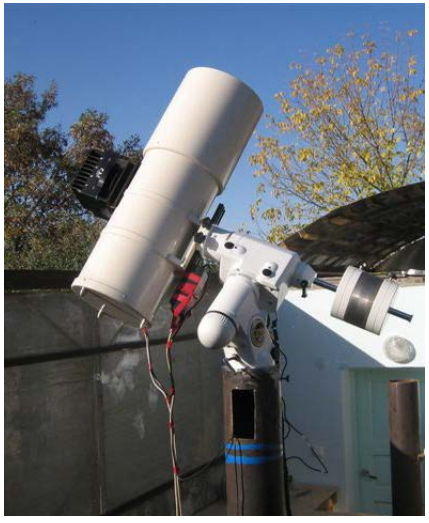
ISON structure

Optical facilities are arranged in four subsets:

- subsystem for surveys of the GEO region (down to 16^m)
- subsystem for tracking of the high orbit faint (fainter than 16^m) space debris at GEO and GTO
- subsystem for tracking of bright GEO and HEO objects
- subsystem for asteroid research

- Four network operation supporting groups:
  - electric and software engineering
  - optical and mount engineering
  - observation planning and data processing
  - new observation technique elaboration

Search and survey subsystem for the GEO region: eleven *22-25 cm telescopes with FOV of 3.5- 5.5 degree*

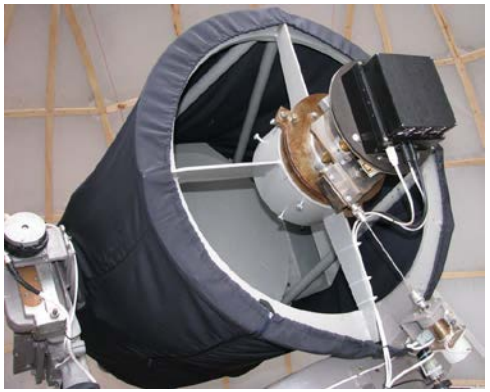






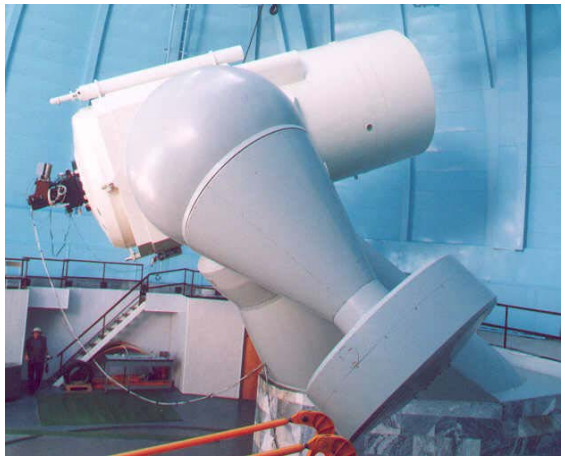
Subsystem for faint debris tracking: eight 40 cm – 70 cm telescopes - AT-64 Nauchny-1, RC-600 Mayaki, S-600 Andrushivka, AZT-8 Gissar, AZT-14 Mondy, Zeiss-600 Arkhyz, ORI-40 in Kitab, ORI-50 in Ussuriysk

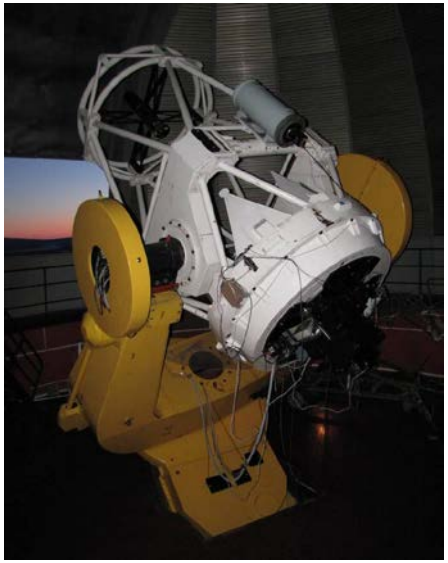


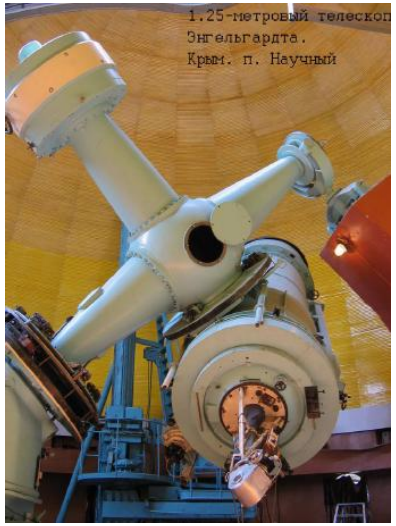





Subsystem for very faint debris tracking – down to 21m: 2.6 m ZTSh Nauchny-1, Zeiss-1000 Teide, Zeiss-2000 Terskol, 1.7 m AZT-33IR Mondy, 1.25 m ZTE Nauchny-2

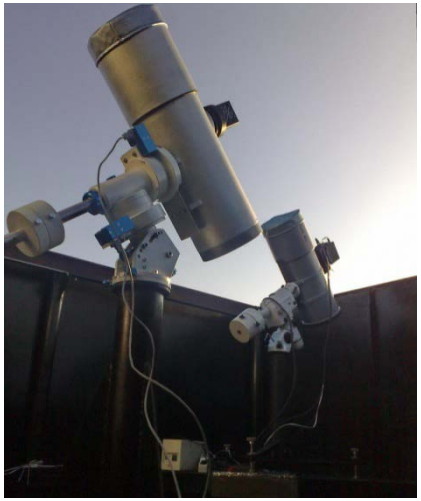






Subsystem for tracking of bright GEO and HEO objects: BNC-250 in Uzhgorod, ORI-25 in Tiraspol, RST-220 in Nauchniy-2, Sajen-TM in Arkhyz, ORI-25 in Blagoveschensk, GAS-250 in Ussuriysk

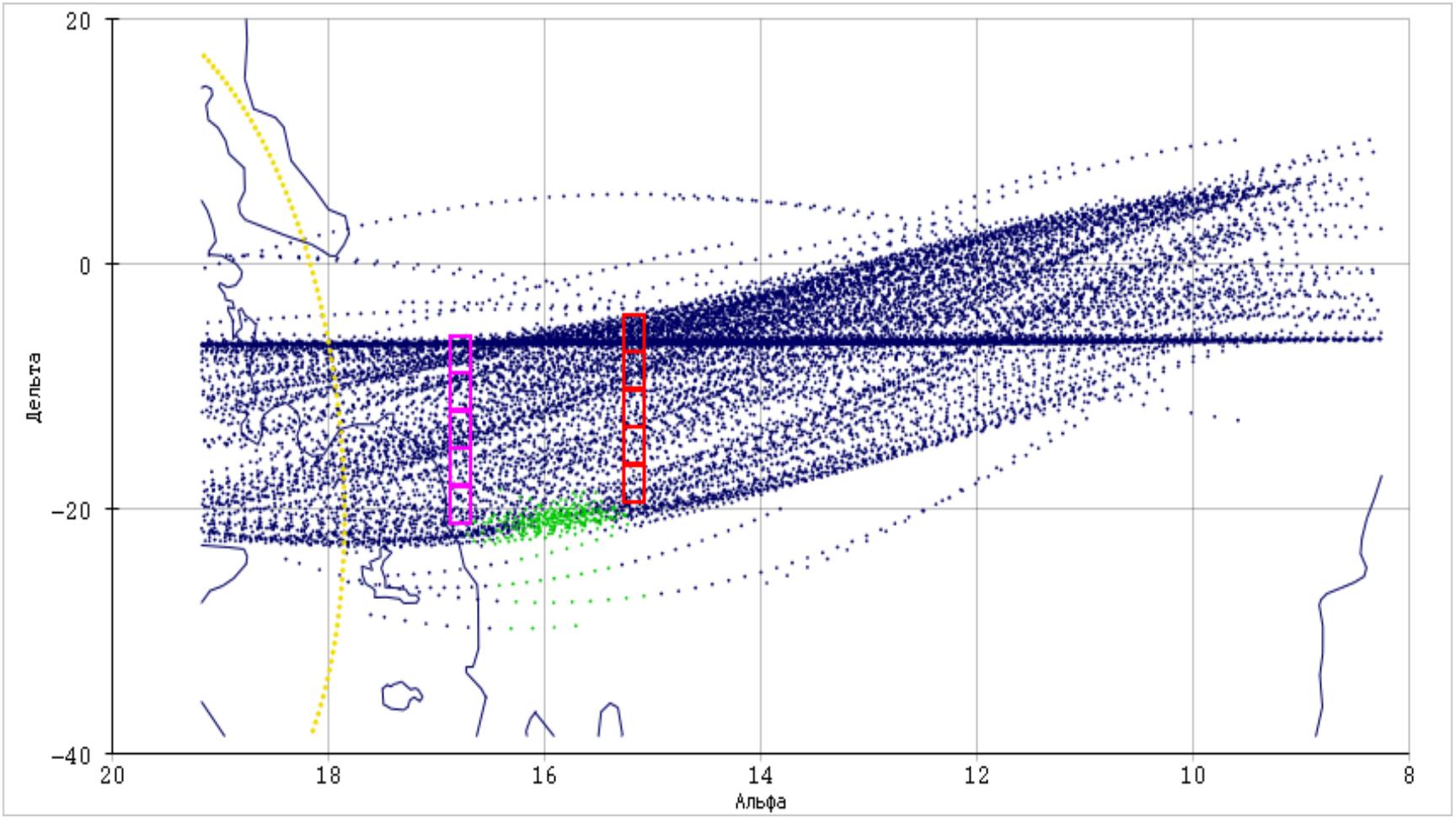


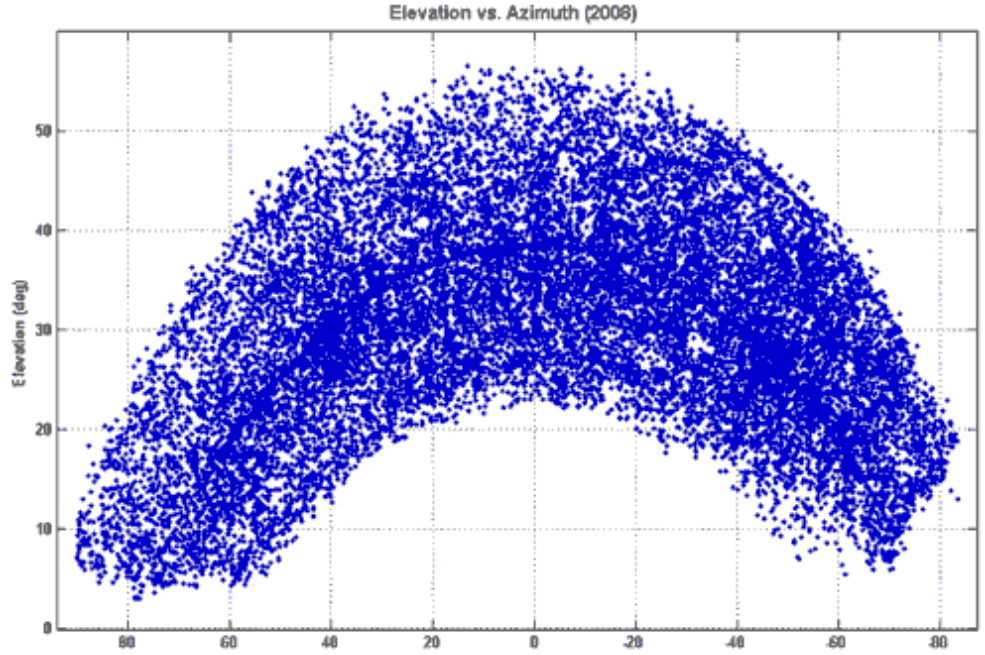
ISON observation arrangement

- telescopes with large FOV of the search and survey subsystem provide regular surveying of the GEO region in 20° width in inclination
- results obtained are analyzed by the observation planning&data processing group using algorithm which allows to find correlation between uncorrelated short tracks in order to discover new objects and to establish their preliminary orbits
- ephemerides for new detected objects are sent to group of telescopes for confirmation follow-up observations
- confirmed objects are classified as “bright” and “faint” based on their brightness - the border between these two groups corresponds to 16.0 magnitude in average at some fixed conditions (phase angle, elevation, range)
- they are added to the orbital archive which is used for ephemerides distributed weekly to telescopes of 2 subsystems – for faint and bright space object tracking

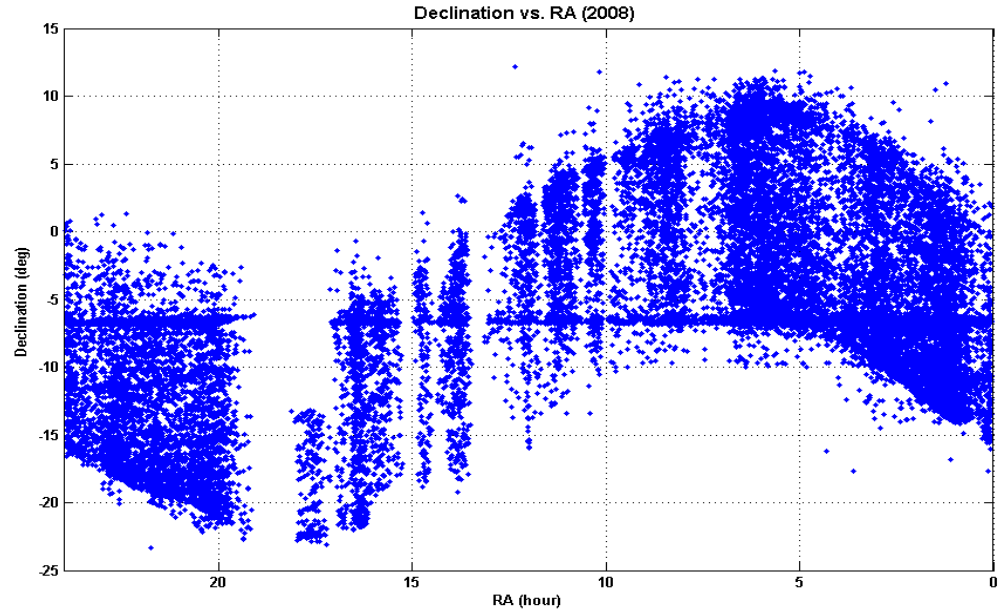
Planning of survey observations: two barriers selects before and after Earth shadow position providing long measuring arc.

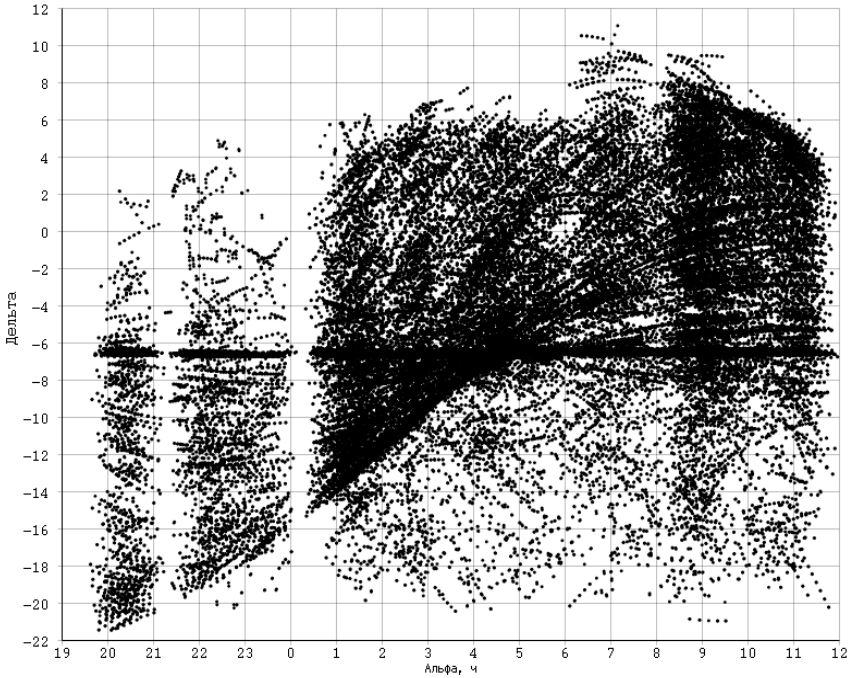


Distribution of the catalogued GEO objects in right ascension – declination plane

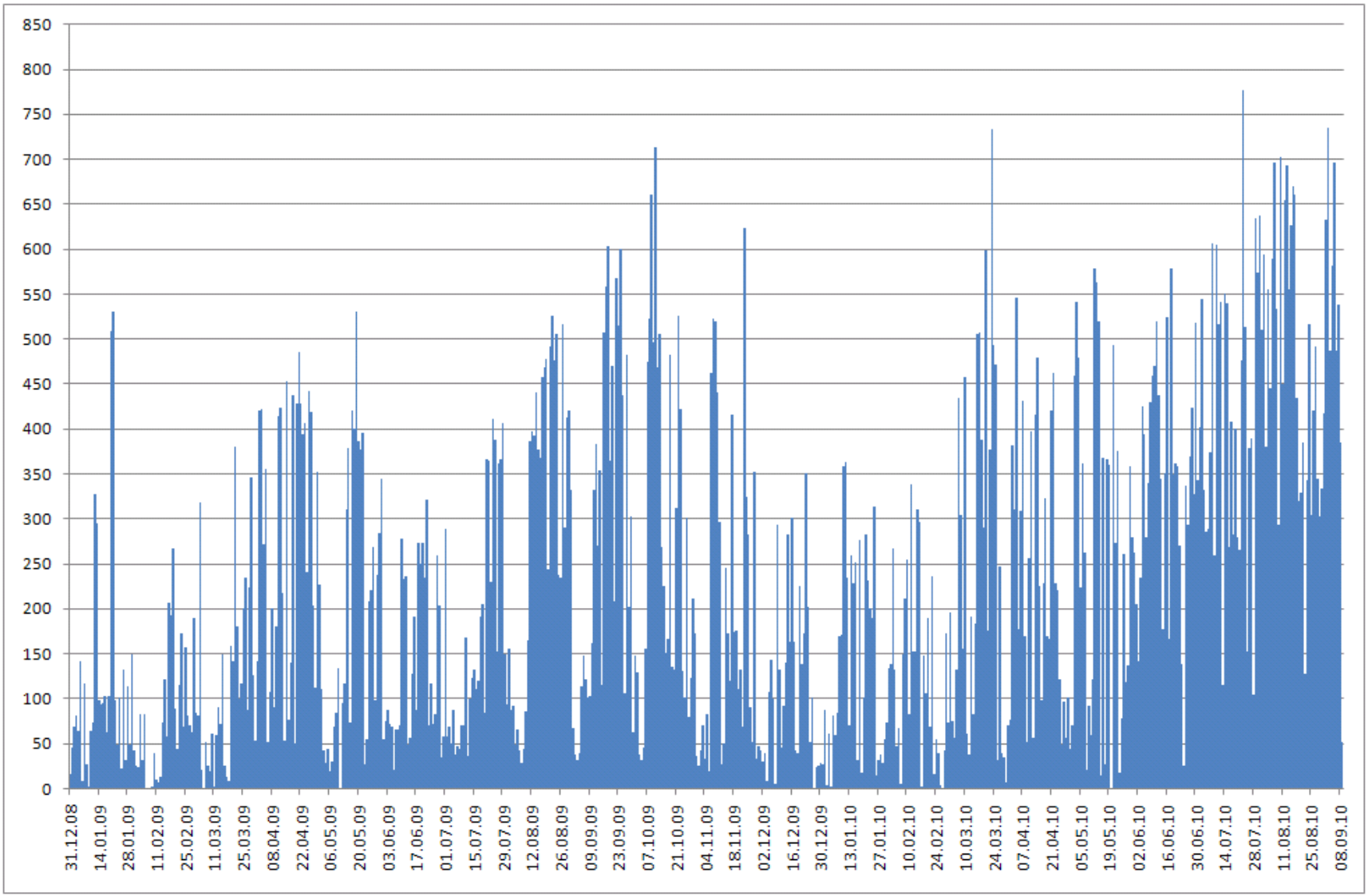


Samples of coverage in GEO surveys of 22-cm telescopes in Nauchniy (FOV 4 degree) and Ussuriysk (FOV 5.5 degree)

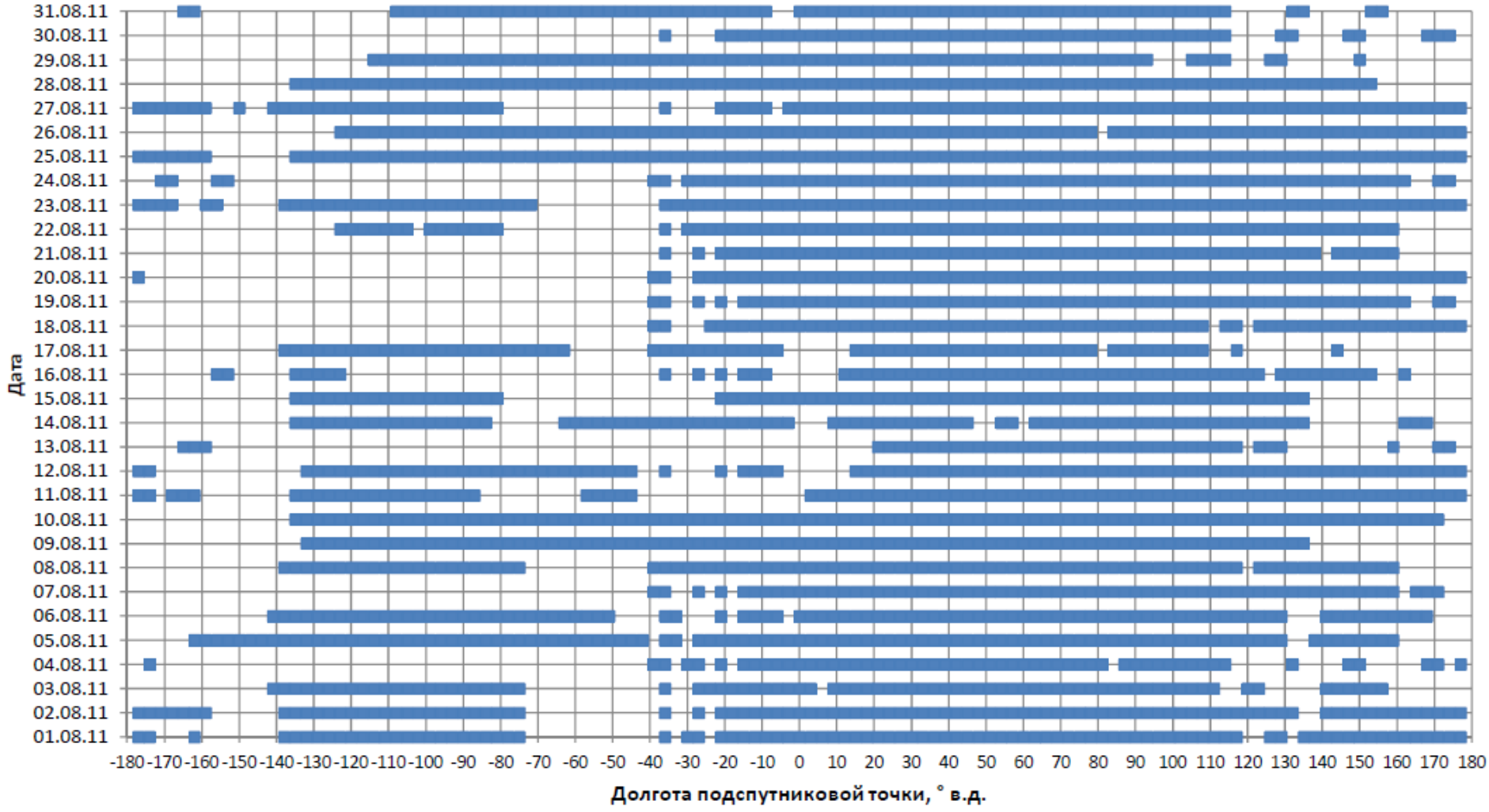




Observed Individual GEO Objects Number (by night, Jan 2009 - Aug 2010)



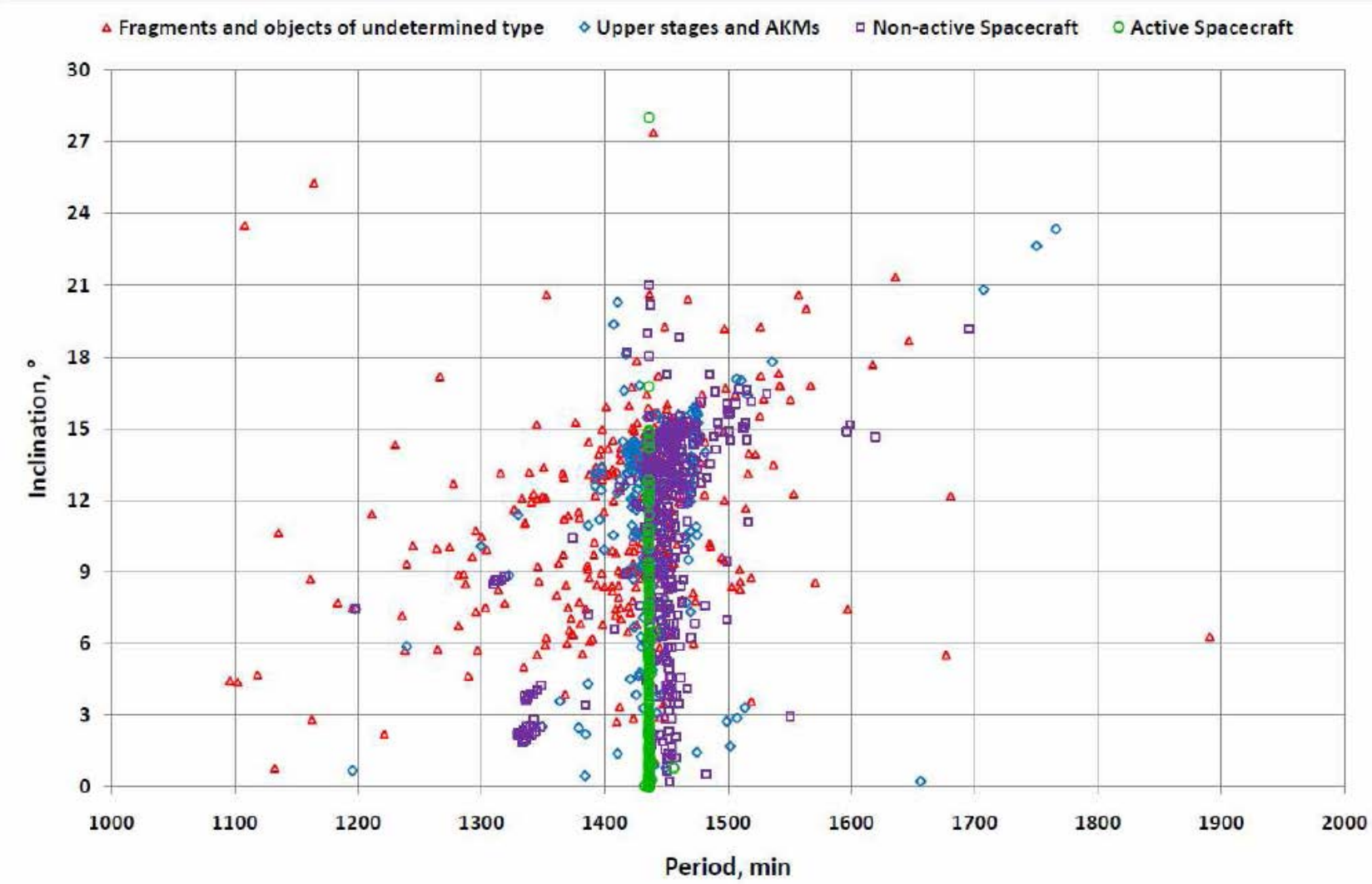
GEO longitude range where satellites were observed by ISON during days of August 2011



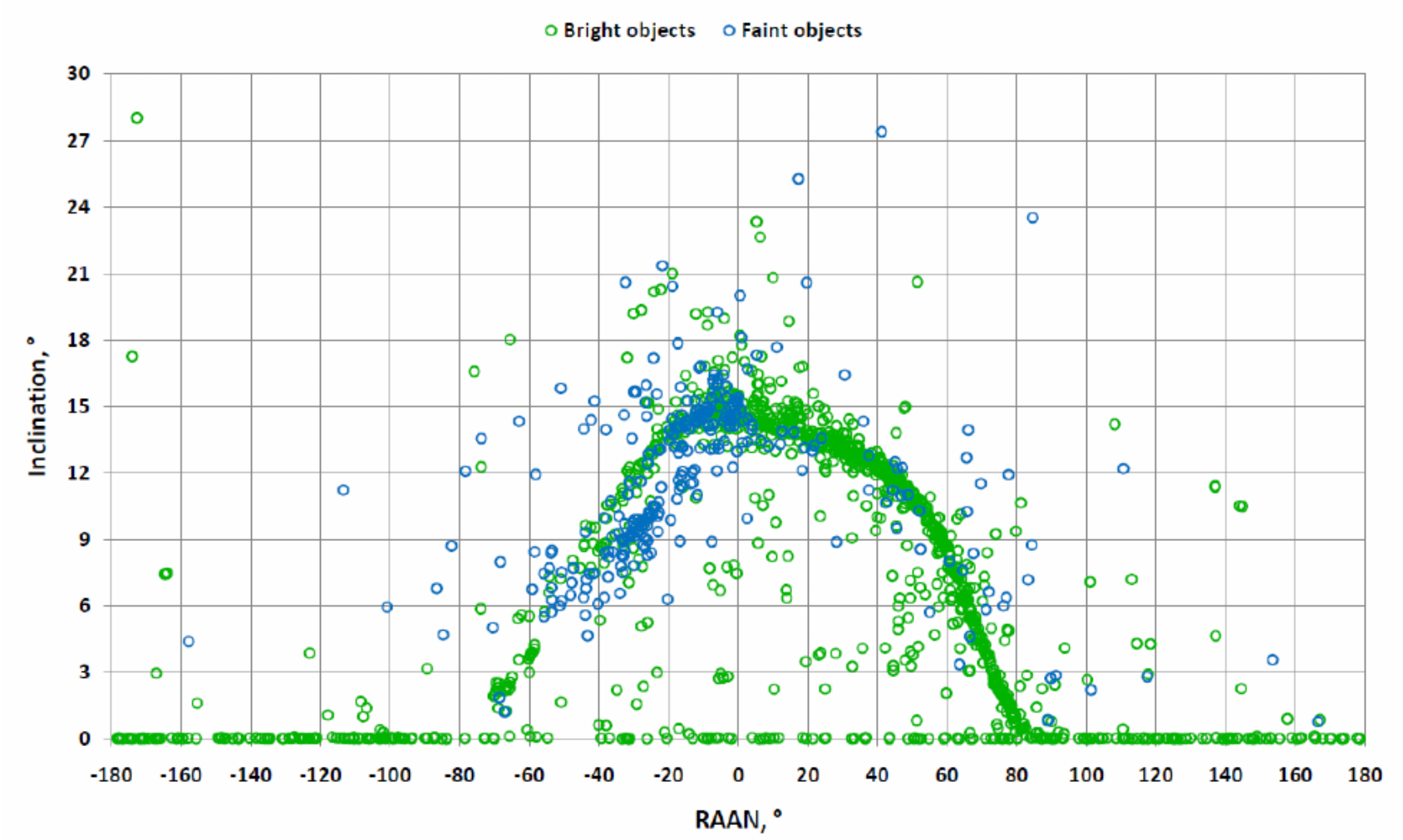
GEO Population
(KIAM database, Feb 1, 2011)

- Total – **1557 objects in GEO region with** orbits maintained routinely, including
- *Spacecraft* – ***922*** (404 under control, 518 non-functional)
- *Upper stages and AKMs* – ***257***
- *Fragments and objects of undetermined type* – ***378***

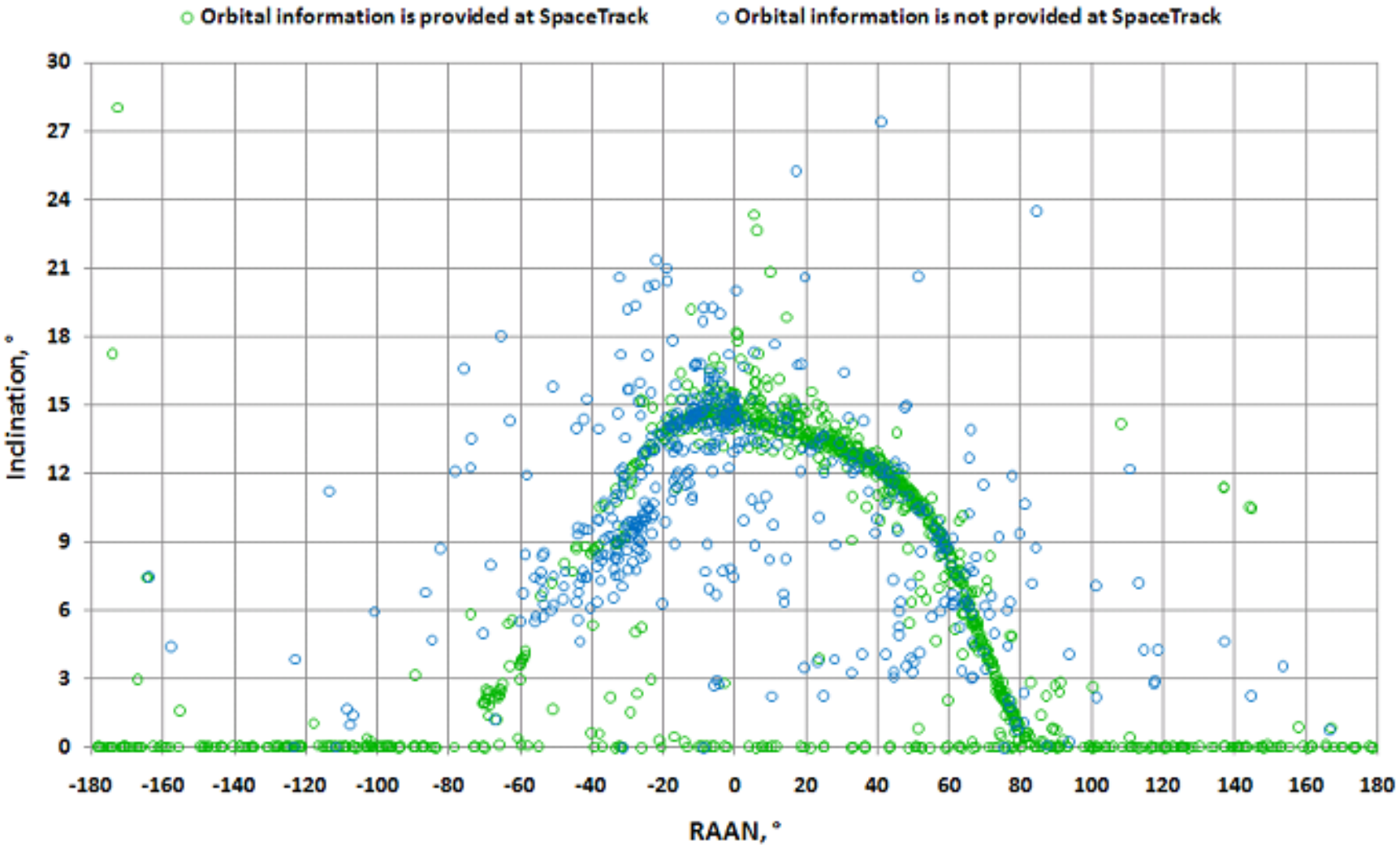
Distribution of 1557 GEO objects by period and inclination



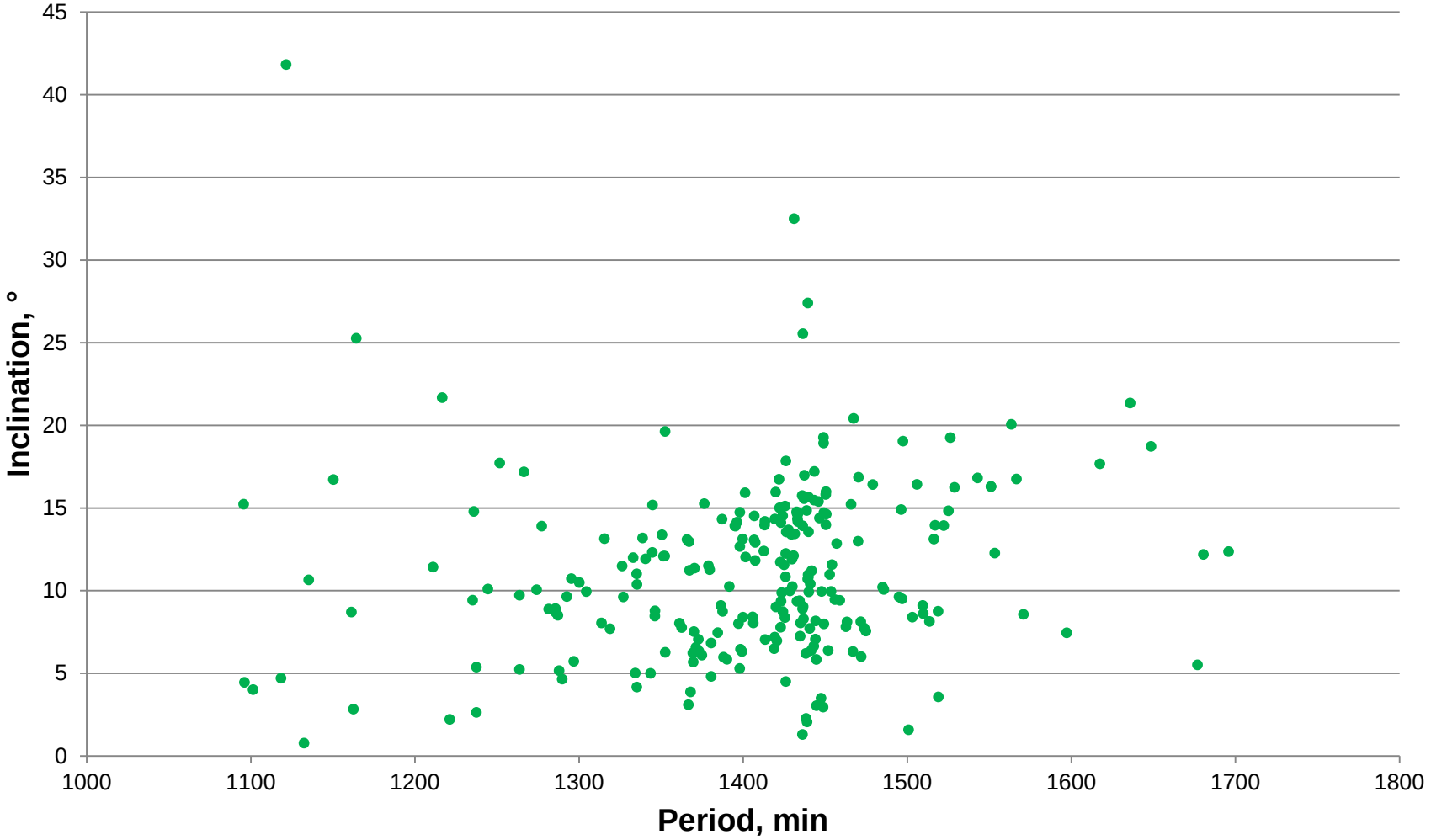
Distribution of 1557 bright (brighter 16 magn) and faint (fainter 16m) GEOobjects by RAAN and inclination



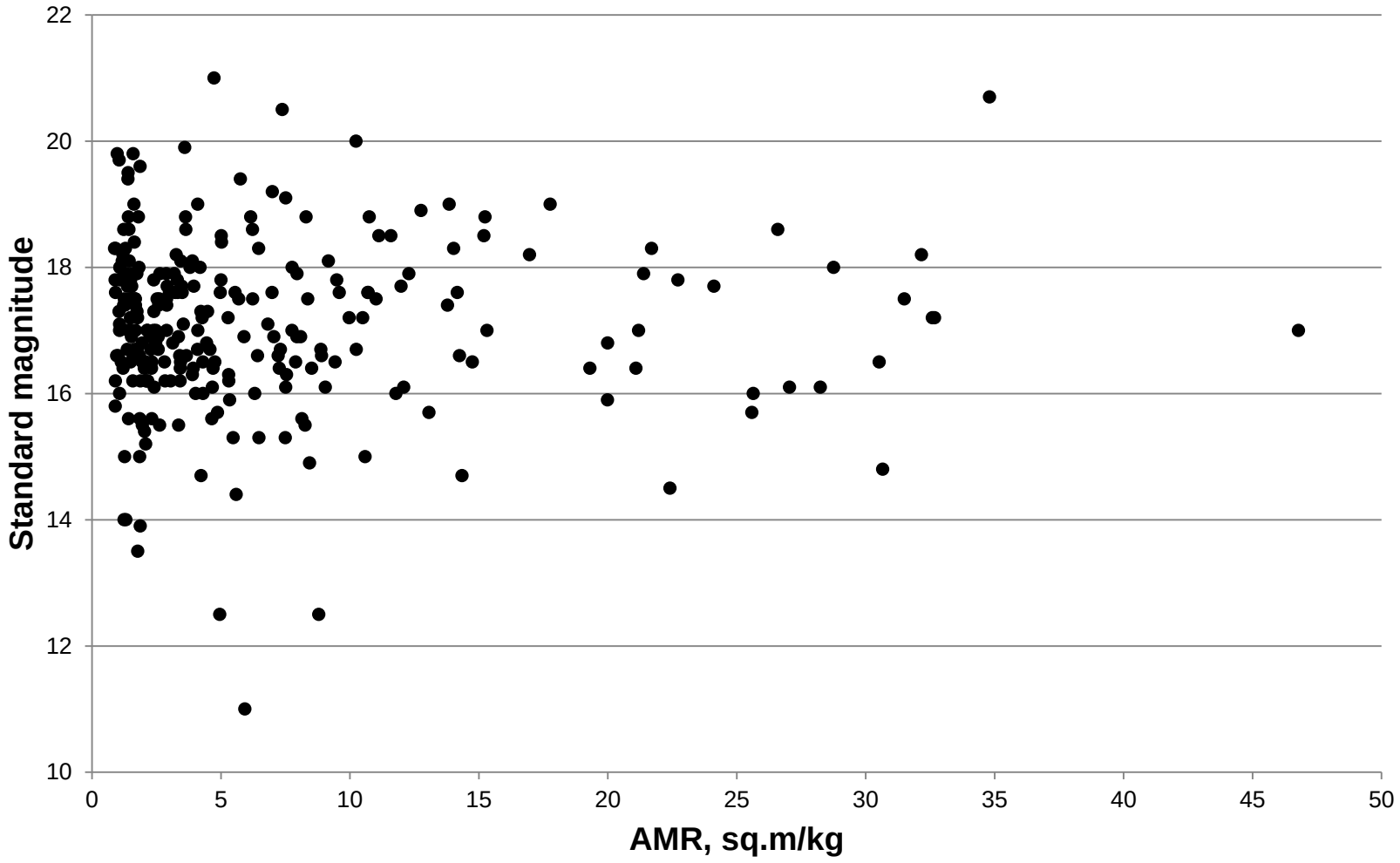
Distribution of 1530 GEO objects by RAAN and Inclination with TLE and without TLE



Distribution of High AMR objects by period and inclination



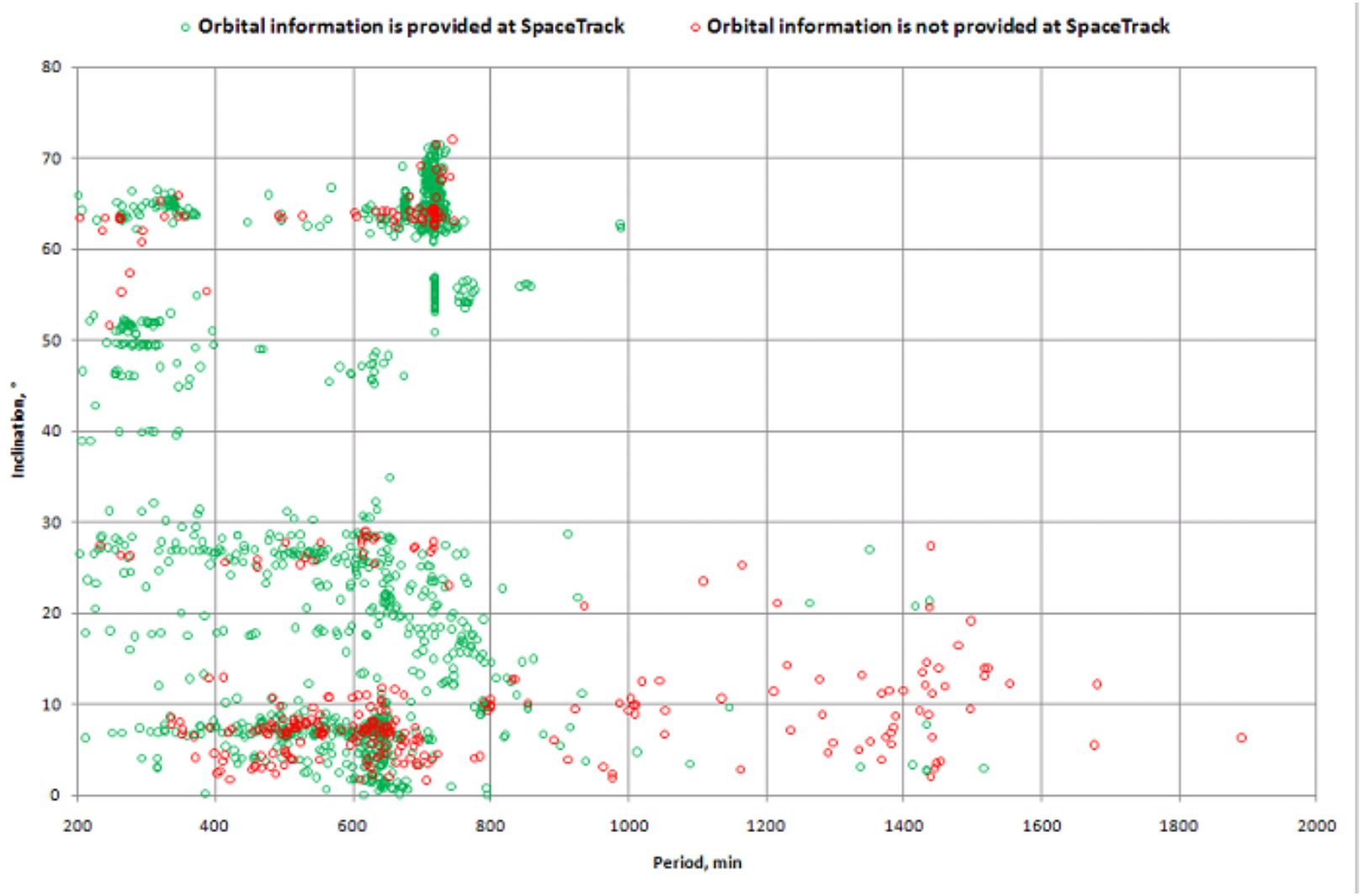
Distribution of High AMR objects by AMR value and standard magnitude



HEO and MEO Objects Measured (KIAM database, Sep 1, 2010)

- **Total – 1699 objects on HEO and MEO with orbits updated occasionally or by tasking, including**
- **Spacecraft – 394**
- **Upper stages and AKMs – 560**
- **Fragments and objects of undetermined type – 744**

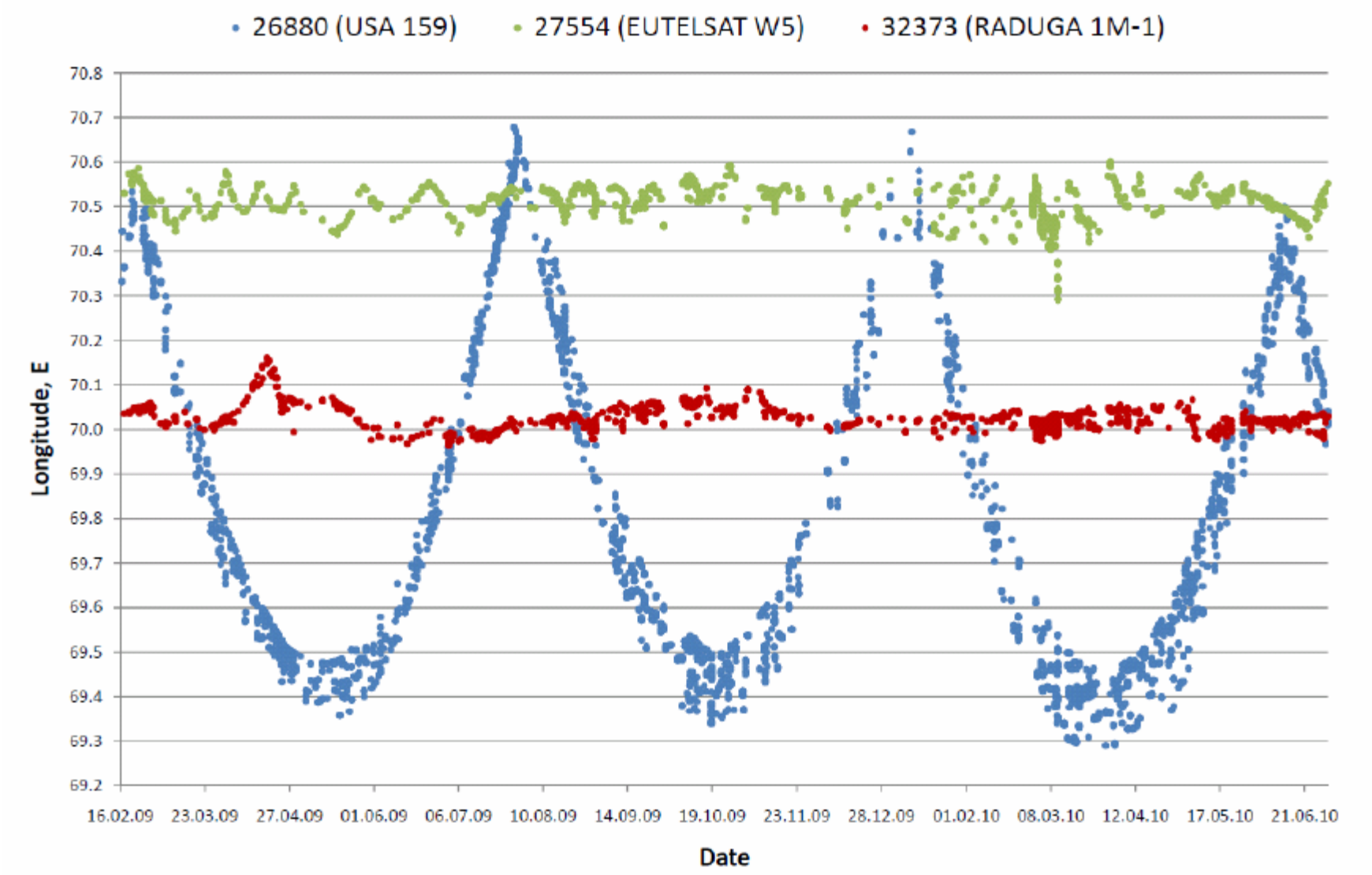
Distribution of 1699 HEO and MEO objects by Period and Inclination



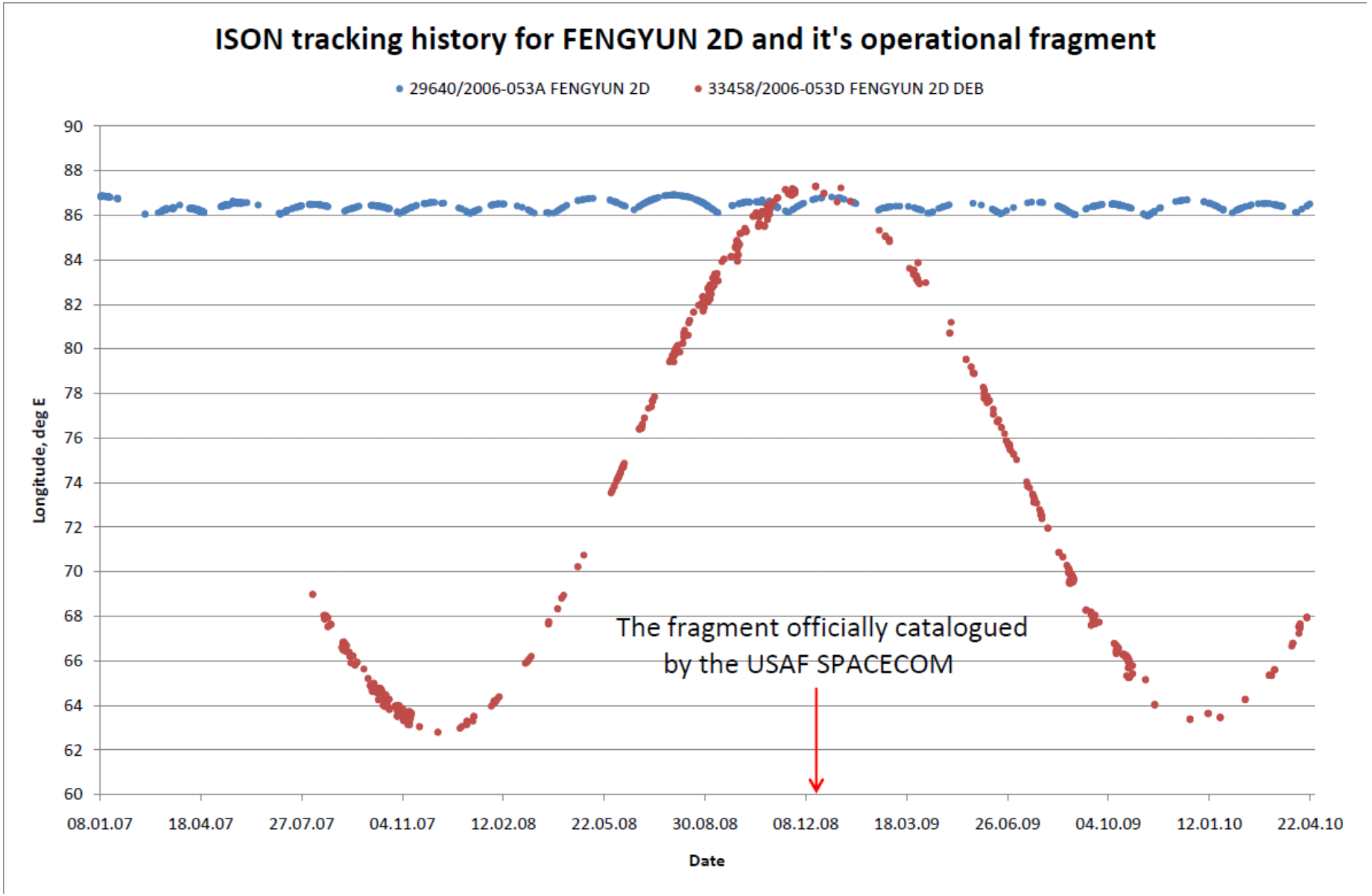
ISON participation in ASPOS OKP project

- **Since 2010 ISON involved into Roscosmos ASPOS OKP project – creation of automated system for prediction of hazardous situations in Near-Earth Space**
- **KIAM is responsible for conjunction analysis and notification at high Earth orbits and uses the ISON data for this goal**
- **Since 2011 KIAM&ISON provides the safety of Electra-L GEO satellite and helps to orbital determination of Radioastron (space radio telescope) spacecraft on extra high elliptical orbit**

Co-located spacecrafts around 70E



Fragment of FENGYUN 2D spacecraft



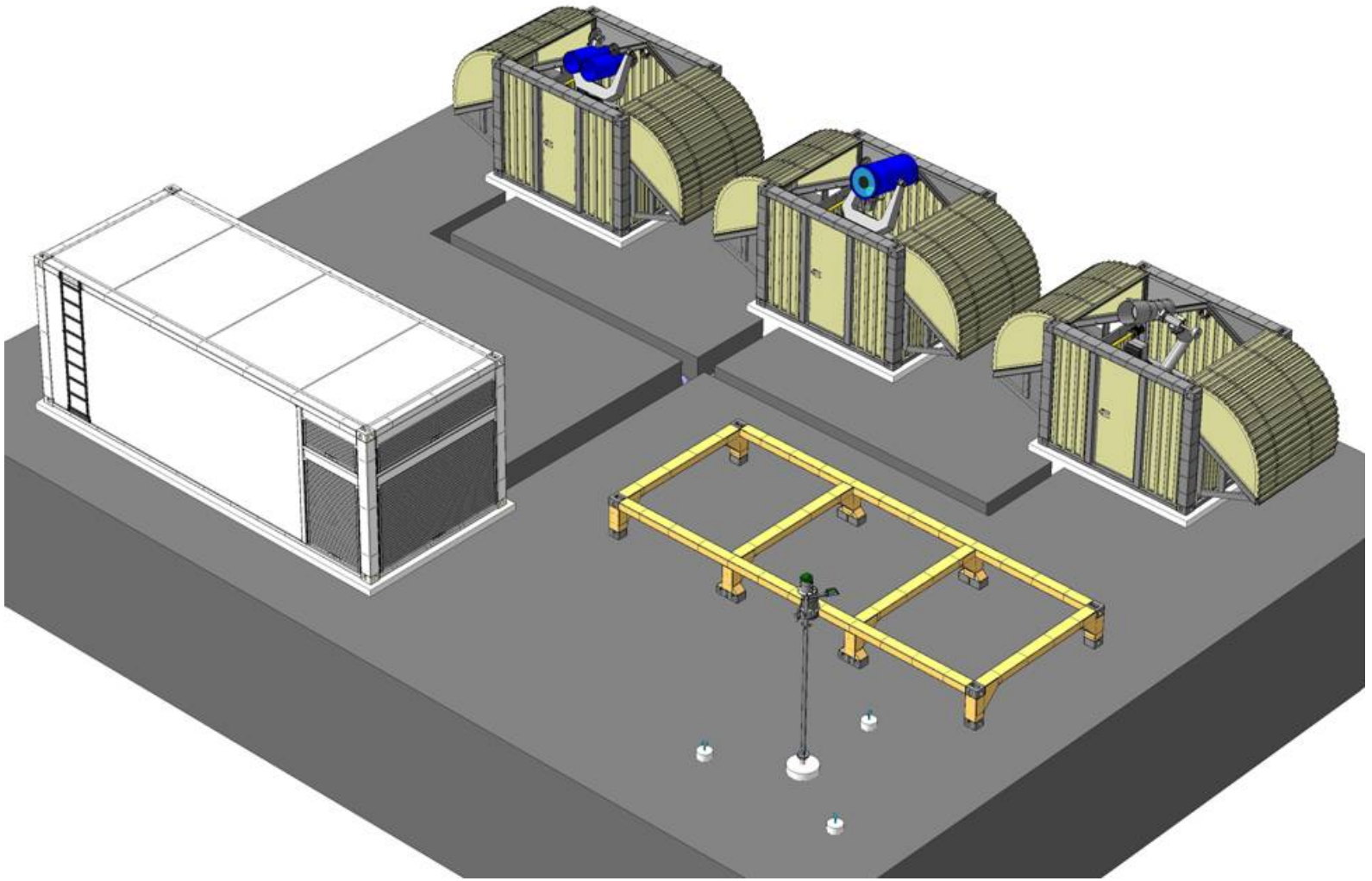
GEO space debris population

- Surprisingly, number of discoveries of relatively bright GEO debris objects (brighter than 16 magnitude) continues to grow. Every month, about 10 such new debris objects are being discovered
- Many of newly discovered GEO space debris are crossing or permanently staying in the GEO protected region and increase threat to operational spacecrafts. It is important to discover as many such debris as possible and understand the sources from which they are originating
- It is expected that at least several hundreds more of GEO space debris brighter than 18^{th} magnitude (which corresponds to 30-40 cm size and larger, assuming standard reflectivity characteristics) exist in the GEO region. Number of fainter (and thus smaller) objects is not yet estimated correctly

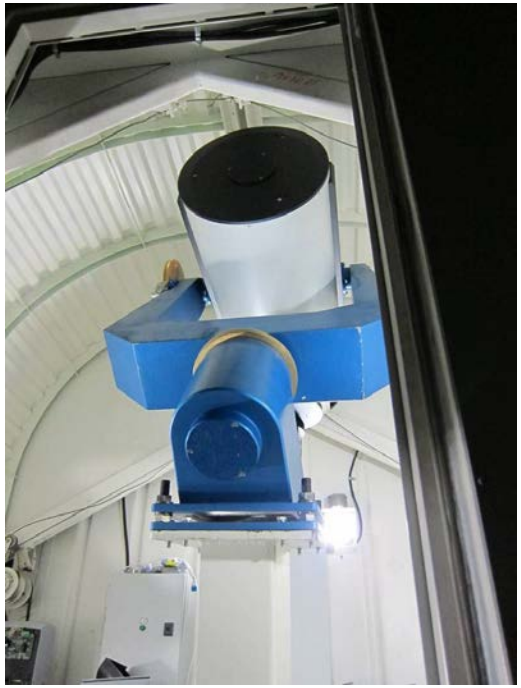
Subnetwork for ASPOS OKP for three Roscosmos grants

- Four dedicated observation facilities EOP-1 with 3 telescopes in each (40-cm, 25 cm and double 19.2 cm)
- Two separate telescopes – 50-cm and 65-cm
- Two dedicated observation facilities EOP-2 with 3 telescopes in each (65-cm, 40-cm, 4x19 cm)
- Modernization of 2.6-m and 1-m Schmidt telescope of Buryakan observatory in Armenia
- Designing of 0.8-m and 1.6-m telescopes

EOP-1 – standard observation facility

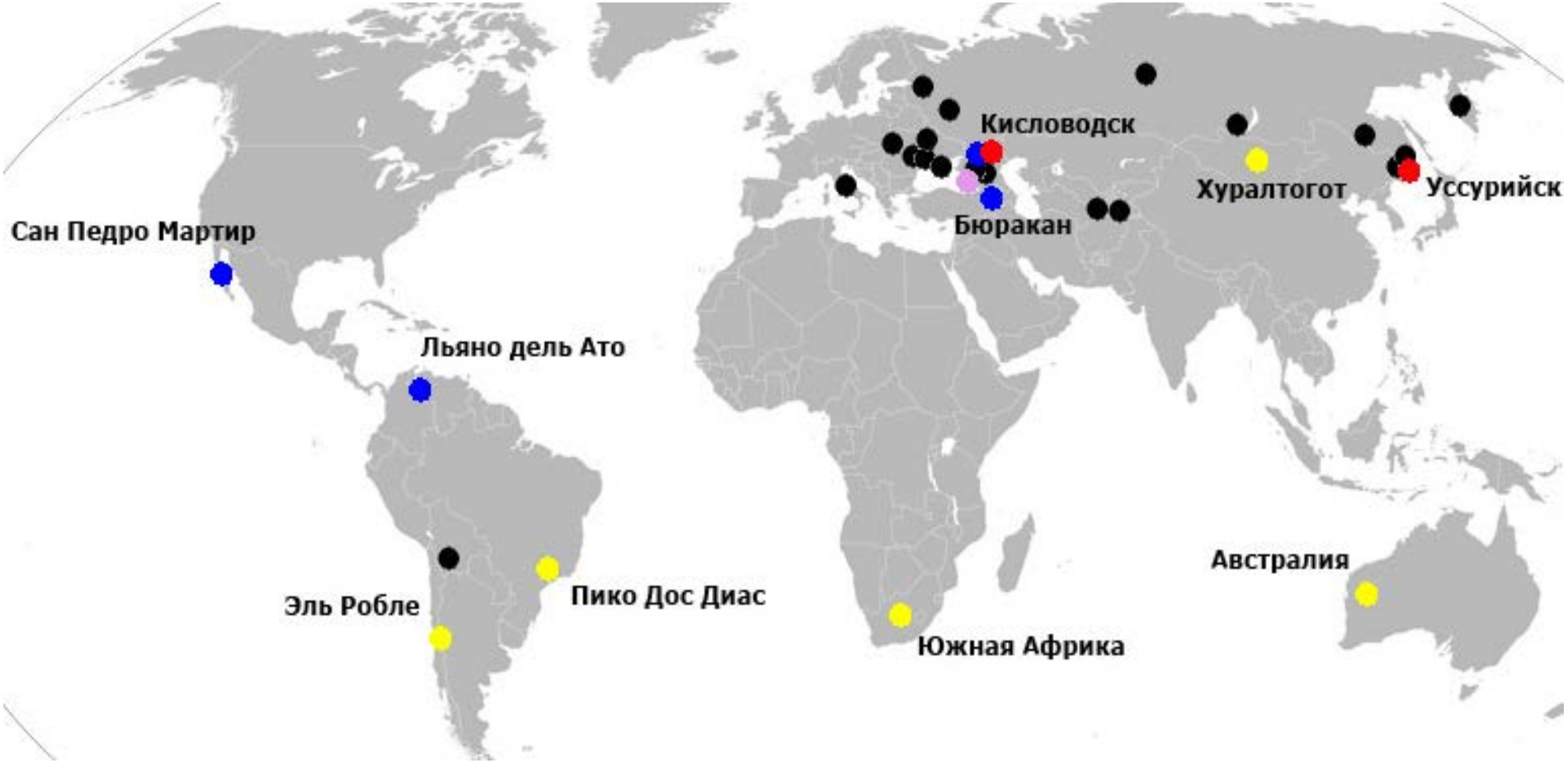


First two EOP-1 already tested



Selected places for installation of three-telescopes dedicated facilities

blue points – first three-telescope (40, 25, 2x19.2) facilities
yellow points – next three-telescope (65, 40, 4x19.2) facilities
red points – 50-cm and 65-cm telescopes



First EOP-1 and 50-cm telescope will be installed near Kilsovodsk in October

Additional subnetwork background

- Double enlarging of volume of ISON data
- increasing regularity of surveys in Western Hemisphere
- providing searching and tracking of faint fragments along whole GEO
- removing the decreasing of volume of data during summer time (observations in South Hemisphere)
- regular HEO observations including surveys
- start of LEO and MEO observations

New series of 19.2-cm telescopes with FOV 7.1x7.1 degree is in production. First such telescope is installed in Sanglok, Tajikistan

The results of first test survey in 30.09.2011

11485 measurements in 1611 tracks for 405 space objects

during observations 9 hours, 47 minutes

Limiting magnitude 14 for 12 s exposure time

Forms of collaboration with ISON project

- Participation in regular ISON coordinated observations
- Joint observation campaigns to exchange the obtained results
- Arrangement of ISON observations for specific scientific goal or program for further joint publications
- Providing of software, elaborated under ISON project for further coordinated activities
- Installation of telescopes, elaborated under ISON project
- Modernization of non-operational obsolete telescopes
- Production of telescope under grant for future joint observations